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HYDRAULIC DRIVE DEVICE
[Yuatsu kido sochi]

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SPECIFICATION /*

[TITLE OF THE INVENTION]

Hydraulic Drive Device

[CLAIMS]

[Claim 1] A hydraulic drive device having first and second variable-displacement hydraulic pumps, a plurality of actuators driven by hydraulic fluid delivered by said first and second variable-displacement hydraulic pumps and containing a slewing motor and a boom cylinder, a first valve group connected to the delivery pipe line of said first variable-displacement hydraulic pump and containing a first direction switching valve for switching the direction of the hydraulic fluid supplied to said slewing motor, and a second valve group connected to the delivery pipe line of said second variable-displacement hydraulic pump and containing a second direction switching valve for switching the direction of the hydraulic fluid supplied to said boom cylinder, characterized by having

drive detecting means for detecting whether or not said slewing motor and boom cylinder are being driven,

boom load detecting means for detecting the bottom pressure of said boom cylinder and outputting a corresponding detection signal, and

limiting means for limiting the delivery flow of said first

* Claim and paragraph numbers correspond to those in the foreign text.

variable-displacement hydraulic pump according to the detection signal from the boom load detecting means when said drive detecting means have detected that said slewing motor and boom cylinder are being driven.

[Claim 2] The hydraulic drive device according to Claim 1, characterized by also having first operating means for controlling the stroke of said first direction switching valve, first degree of operation detecting means for detecting the degree of operation of these first operating means and outputting a corresponding degree of operation signal, second operating means for controlling the stroke of said second direction switching valve, second degree of operation detecting means for detecting the degree of operation of these second operating means and outputting a corresponding degree of operation signal, first setting means for setting a first target displacement of said first variable-displacement hydraulic pump according to the degree of operation signal from said first degree of operation detecting means, and first pump control means for controlling the displacement of said first variable-displacement hydraulic pump based on this first target displacement; and said drive detecting means assessing whether the degree of operation signals from said first and second degree of operation detecting means are greater than a predetermined blind area level, said limiting means having first selection means for selecting and outputting the lower of said first target displacement and said second target displacement, and said

first pump control means controlling the displacement of said first variable-displacement hydraulic pump based on the target displacement outputted by said first selecting means.

[Claim 3] The hydraulic drive device according to Claim 1, characterized by also having resistance means placed below a center bypass line passing through said first direction switching valve for generating a control pressure according to the flow of hydraulic fluid flowing below said center bypass line, pressure detecting means for detecting the control pressure generated by these resistance means and outputting a corresponding pressure detection signal, third setting means for setting a third target displacement of said first variable-displacement hydraulic pump according to the pressure detection signal from these pressure detecting means, second pump control means for controlling the displacement of said first variable-displacement hydraulic pump based on this third target displacement, first operating means for controlling the stroke of said first direction switching valve, first degree of operation detecting means for detecting the degree of operation of these first operating means and outputting a corresponding degree of operation signal, second operating means for controlling the stroke of said second direction switching valve, and second degree of operation detecting means for detecting the degree of operation of these second operating means and outputting a corresponding degree of operation signal; and said drive detecting means assessing whether the degree

of operation signals from said first and second degree of operation detecting means are greater than a predetermined blind area level, said limiting means having fourth setting means for setting a fourth target displacement of said first variable-displacement hydraulic pump according to the detection signal from said boom load detecting means and second selection means for selecting and outputting the lower of said third target displacement and said fourth target displacement, and said second pump control means controlling the displacement of said first variable-displacement hydraulic pump based on the target displacement outputted by said second selecting means.

[DETAILED EXPLANATION OF THE INVENTION]

[0001] [INDUSTRIAL FIELD OF APPLICATION]

The present invention relates to a hydraulic drive device for driving the operating machinery of a hydraulic drive.

[0002] [PRIOR ART]

An example of prior art related to this type of hydraulic drive device is International Patent No. WO 92/18710. In this prior art, an operator selects through a selection device from three types of pump flow characteristics stored in the ROM of a controller, and the delivery flow of a hydraulic pump is controlled according to this selected pump flow characteristic. As a result, the control characteristics (negative control characteristics) of direction switching valves are switched according to the nature of the operation, thereby assuring good operation for different types of

operations.

[0003] [PROBLEMS THAT THE INVENTION IS TO SOLVE]

The operation of raising a slewing boom usually occurs frequently when operating a hydraulic shovel, and often involves repeatedly passing a bucket through the same path. Therefore, by selecting pump flow characteristics according to the type of operation, the prior art cited above can carry out an operation efficiently with little energy compared to using the same pump flow characteristic for all operations. For example, a first pump flow characteristic may be provided for a good pump flow characteristic demanding much operation, such as an excavation loading operation, and this first pump characteristic may be selected when operating to raise a slewing boom. This prior art, however, does not consider change in the weight of the load in the bucket during the operation of raising this slewing boom. Changing the weight of the load in the bucket during an operation changes the maximum flow which can be delivered by the pump. Therefore, in such a case, the operator must increase or decrease operation of a lever according to the weight of the load in the bucket such that the bucket passes through the same movement path. This is a cumbersome operation that increases the operational burden on the operator for adjustment.

[0004] The object of the present invention is to provide a hydraulic drive device capable of lessening the operational burden on an operator to adjust the movement path of a bucket during the

operating of raising the slewing boom of a hydraulic shovel.

[0005] [MEANS OF SOLVING THE PROBLEMS]

To achieve this object, the present invention provides a hydraulic drive device having first and second variable-displacement hydraulic pumps, a plurality of actuators driven by hydraulic fluid delivered by the first and second variable-displacement hydraulic pumps and containing a slewing motor and a boom cylinder, a first valve group connected to the delivery pipe line of the first variable-displacement hydraulic pump and containing a first direction switching valve for switching the direction of the hydraulic fluid supplied to the slewing motor, and a second valve group connected to the delivery pipe line of the second variable-displacement hydraulic pump and containing a second direction switching valve for switching the direction of the hydraulic fluid supplied to the boom cylinder, characterized by having drive detecting means for detecting whether or not the slewing motor and boom cylinder are being driven, boom load detecting means for detecting the bottom pressure of the boom cylinder and outputting a corresponding detection signal, and limiting means for limiting the delivery flow of the first variable-displacement hydraulic pump according to the detection signal from the boom load detecting means when the drive detecting means have detected that the slewing motor and boom cylinder are being driven.

[0006] In a preferred mode, the present invention provides a hydraulic drive device characterized by also having first operating

means for controlling the stroke of the first direction switching valve, first degree of operation detecting means for detecting the degree of operation of these first operating means and outputting a corresponding degree of operation signal, second operating means for controlling the stroke of the second direction switching valve, second degree of operation detecting means for detecting the degree of operation of these second operating means and outputting a corresponding degree of operation signal, first setting means for setting a first target displacement of the first variable-displacement hydraulic pump according to the degree of operation signal from the first degree of operation detecting means, and first pump control means for controlling the displacement of the first variable-displacement hydraulic pump based on this first target displacement; and the drive detecting means assessing whether the degree of operation signals from the first and second degree of operation detecting means are greater than a predetermined blind area level, the limiting means having first selection means for selecting and outputting the lower of the first target displacement and the second target displacement, and the first pump control means controlling the displacement of the first variable-displacement hydraulic pump based on the target displacement outputted by the first selecting means.

[0007] In another preferred mode, the present invention provides a hydraulic drive device characterized by also having resistance

means placed below a center bypass line passing through the first direction switching valve for generating a control pressure according to the flow of hydraulic fluid flowing below the center bypass line, pressure detecting means for detecting the control pressure generated by these resistance means and outputting a corresponding pressure detection signal, third setting means for setting a third target displacement of the first variable-displacement hydraulic pump according to the pressure detection signal from these pressure detecting means, second pump control means for controlling the displacement of the first variable-displacement hydraulic pump based on this third target displacement, first operating means for controlling the stroke of the first direction switching valve, first degree of operation detecting means for detecting the degree of operation of these first operating means and outputting a corresponding degree of operation signal, second operating means for controlling the stroke of the second direction switching valve, and second degree of operation detecting means for detecting the degree of operation of these second operating means and outputting a corresponding degree of operation signal; and the drive detecting means assessing whether the degree of operation signals from the first and second degree of operation detecting means are greater than a predetermined blind area level, the limiting means having fourth setting means for setting a fourth target displacement of the first variable-displacement hydraulic pump according to the detection

signal from the boom load detecting means and second selection means for selecting and outputting the lower of the third target displacement and the fourth target displacement, and the second pump control means controlling the displacement of the first variable-displacement hydraulic pump based on the target displacement outputted by the second selecting means.

[0008] Specifically, by configuring the present invention in this way, when an operator wishing to raise a slewing boom operates the first direction switching valve and the second direction switching valve, first, a hydraulic fluid conducted through a delivery pipe line from a first variable-displacement hydraulic pump is supplied through a first direction switching valve disposed in a first valve group to a slewing motor, which drives the slewing motor to swing the upper swinging section of a hydraulic shovel. At the same time, a hydraulic fluid conducted through a delivery pipe line from a second variable-displacement hydraulic pump is supplied through a second direction switching valve disposed in a second valve group to a boom cylinder, which extends the boom cylinder to raise the boom of the hydraulic shovel. This executes the operation of raising the slewing boom. The drive detecting means also detect the drive states of the slewing motor and the boom cylinder.

[0009] When the drive detecting means thus detect the state of raising the slewing boom, the boom load detecting means detect the bottom pressure of the boom cylinder - that is, the load applied to

the boom - and output a detection signal, and the limiting means limit the delivery flow of the first variable-displacement hydraulic pump according to this detection signal. Specifically, when exercising so-called positive control, for example, the first setting means set a first target displacement according to the degree of operation of the first operating means controlling the stroke of the first direction switching valve. If the degree of operation of the first and second operating means controlling the strokes of the first and second variable-displacement hydraulic pumps is greater than a predetermined blind area level, however, the drive detecting means assess that the boom cylinder and the slewing motor are in drive states, and the second setting means provided to the limiting means set a second target displacement according to the detection signal from the boom load detecting means. Next, the first selecting means select the lower of the first target displacement and the second target displacement. The first pump control means then control the displacement of the first variable-displacement hydraulic pump according to this selected target displacement. Therefore, when the detection signal from the boom load detecting means increases, causing the second setting means to set a lower second target displacement, if the weight inside the bucket is light, producing a lighter load, the second target displacement is higher than the first target displacement. Therefore, the first selecting means select the first target displacement, and the first pump control means exercise

normal pump control using the first target displacement. If the weight inside the bucket is heavy, however, producing a heavier load, the second target displacement is lower than the first target displacement. Therefore, the first selecting means select the second target displacement, and the first pump control means exercise pump control using the second target displacement.

[0010] When exercising so-called negative control, for example, resistance means located below the center bypass line passing through the first direction switching valve generate a control pressure according to the flow of hydraulic fluid. The pressure detecting means detect this control pressure, and the third setting means set a third target displacement according to this control pressure. The first and second degree of operation detecting means detect the degree of operation of the first and second operating means for controlling the stroke of the first and second direction switching valves, and if these degrees of operation are greater than a predetermined blind area level, the drive detecting means assess that the boom cylinder and the slewing motor are in drive states. Next, the fourth setting means provided to the limiting means set a fourth target displacement according to the detection signal from the boom load detecting means, and the second selecting means selects the lower of these third and fourth target displacements. Next, the second pump control means controls the displacement of the first variable-displacement hydraulic pump according to this selected

target displacement. Therefore, if the fourth target displacement is set beforehand in the fourth setting means to a lower level if the detection signal from the boom load detecting means is greater, the fourth target displacement is greater than the third target displacement if the weight inside the bucket is light, producing a lighter load. Consequently, the second selecting means selects the third target displacement, and the second pump control means exercise standard pump control using the third target displacement. If the weight inside the bucket is heavy, however, producing a heavier load, the fourth target displacement is lower than the third target displacement. Therefore, the second selecting means select the fourth target displacement, and the second pump control means exercise pump control using the fourth target displacement, which is lower than the third target displacement.

[0011] Specifically, as noted earlier, raising a slewing boom increases the load. This reduces the delivery flow from the first variable-displacement pump and slows the swinging speed to a corresponding extent even if the boom elevation speed is slow, thus keeping a good balance between the degree of raising and the degree of swinging of the boom.

[0012] [BEST MODE FOR CARRYING OUT THE INVENTION]

Next, embodiments of the present invention will be discussed while referring to the appended drawings. A first embodiment of the present invention will be discussed using Figs. 1 to 6. This

embodiment is applied to a hydraulic shovel, and relates to an embodiment when controlling the delivery flow of a pump by so-called positive control matching the maximum operating pressure of a direction switching valve.

[0013] Although not specifically shown in the drawings, a hydraulic shovel applying a hydraulic drive device according to this embodiment has a left track belt and a right track belt forming a traveling section, a swinging section formed on this travel section, comprising a main section on which a driver’s seat is disposed, and driven by a slewing motor (shown in Fig. 1 to be discussed later), a boom disposed capable of rotating in front of this swinging section and driven by a boom cylinder (shown in Fig. 1 to be discussed later), an arm disposed capable of rotating on this boom and driven by an arm cylinder, and a bucket disposed capable of rotating on this arm and driven by a bucket cylinder.

[0014] Fig. 1 shows the hydraulic pressure circuit of a hydraulic drive device according to the present invention. In Fig. 1, the hydraulic drive device according to this embodiment is provided with variable-displacement hydraulic pumps 2a and 2b and a fixed-displacement pilot pump 4, with a right travel motor (not shown) for driving the right track belt, a bucket cylinder (not shown), and an arm cylinder 8a as an actuator for driving using hydraulic fluid delivered from the hydraulic pump 2a, and with a slewing motor 8b, an arm cylinder (not shown), and a left travel motor (not shown) for

driving the left track belt as an actuator for driving using hydraulic fluid delivered from the hydraulic pump 2b.

[0015] The hydraulic pumps 2a and 2b are connected to a direction switching valve group for switching the direction of the flow of hydraulic fluid to each of the actuators. First, a right travel direction switching valve 7c for control of driving the right travel motor, a bucket direction switching valve 7d for control of driving the bucket cylinder, and a boom direction switching valve 7a for control of driving the boom cylinder 8a are connected in parallel to the hydraulic pump 2a. All of these direction switching valves are pilot-operated valves driven by a pilot pressure, and are center bypass valves provided with a meter-in route and a meter-out route, in which this center bypass route is connected as shown in Fig. 1 to the right travel direction switching valve 7c, the bucket direction switching valve 7d, and the boom direction switching valve 7a in this order. The right travel direction switching valve 7c and the bucket direction switching valve 7d are not strictly elements of this embodiment and may use conventional configurations, for which reason, they are abbreviated in the drawings.

[0016] Next, a swinging direction switching valve 7b for control of driving the slewing motor 8b, an arm direction switching valve 7e for control of driving the arm cylinder, and a left travel direction switching valve 7f for control of driving the left travel motor are connected in parallel to the hydraulic pump 2b. All of these

direction switching valves are likewise center bypass pilot-operated valves as discussed above, in which the center bypass route is connected as shown in Fig. 1 to the swinging direction switching valve 7b, the arm direction switching valve 7e, and the left travel direction switching valve 7f in this order. The arm direction switching valve 7e and the left travel direction switching valve 7f are not strictly elements of this embodiment and may use conventional configurations, for which reason, they are abbreviated in the drawings.

[0017] As noted earlier, all of these direction switching valves 7a to 7f are pilot-operated valves driven by a pilot pressure. To discuss this operation taking the example of the boom direction switching valve 7a, which is an element of the present invention, a pilot pressure generated by the pilot pump 4 is conducted through a pipe line 6a to a boom pilot valve 10 and reduced in pressure, then conducted through a pipe line 16a or 16b to a signal port 17a or 17b of the boom direction switching valve 7a according to the operating direction of an operating lever 10A of the boom pilot valve 10. Similarly, for the swinging direction switching valve 7b, the pilot pressure from the pilot pump 4 is conducted through a pipe line 6b to a swinging pilot valve 11 and reduced in pressure, then conducted through a pipe line 18a or 18b to a signal port 19a or 19b of the swinging direction switching valve 7b according to the operating direction of an operating lever 11A of the swinging pilot valve 11.

Although not specifically discussed, the same operation is used to switch the other direction switching valves 7c to 7f.

[0018] Pressure detectors 12a to 12d, 13a, 13b, and 14 are disposed in the hydraulic drive device of this embodiment for detecting this pilot pressure, a pump delivery pressure, and a load pressure and outputting a corresponding signal to a control section 15. An operating pressure detector 12a detects, through shuttle valves 5c, 5b, and other shuttle valves (not shown), the highest of the pilot pressures for operating the direction switching valves 7c, 7d, and 7a connected to the delivery pipe line of the hydraulic pump 2a, and outputs a corresponding pressure signal S_{ia} to the control section 15. A boom elevation operating pressure detector 12b is connected to the pipe line 16a, and detects that the operating lever 10A of the boom pilot valve 10 has been operated and outputs a corresponding pressure signal S_{bm} to the control section 15. A swing operating pressure detector 12c is connected through a shuttle valve 5d to the pipe lines 18a and 18b, and detects in which direction the operating lever 11A of the swinging pilot valve 11 has been operated and outputs a corresponding pressure signal S_{sw} to the control section 15. An operating pressure detector 12d detects, through shuttle valves 5d, 5e, and other shuttle valves (not shown), the highest of the pilot pressures for operating the direction switching valves 7b, 7e, and 7f connected to the delivery pipe line of the hydraulic pump 2b, and outputs a corresponding pressure signal S_{ib} to the control

section 15. A pump delivery pressure detector 13a is connected to the delivery pipe line of the hydraulic pump 2a, and detects the delivery pressure of the hydraulic pump 2a and outputs a corresponding delivery pressure signal P_a to the control section 15. A pump delivery pressure detector 13b is connected to the delivery pipe line of the hydraulic pump 2b, and detects the delivery pressure of the hydraulic pump 2b and outputs a corresponding delivery pressure signal P_b to the control section 15. A boom cylinder pressure detector 14 is connected to the bottom of the boom cylinder 8a, and detects the bottom pressure and outputs a corresponding boom cylinder bottom pressure signal P_{bm} to the control section 15.

[0019] The control section 15 carries out specific calculations (to be discussed later) based on the detection signals from the pressure detectors 12a to 12d, 13a, 13b, and 14, and outputs drive signals to regulators 3a and 3b controlling the delivery flow (tilt angle) of the hydraulic pumps 2a and 2b to set the tilt angles of the pumps 2a and 2b as predetermined target delivery flows (target tilt angles) Q_a and Q_b (to be discussed later).

[0020] The operations within these configurations will be discussed following Fig. 2, which shows a flowchart giving the details of the calculation process by the control section 15. In Fig. 2, first, in procedure 20, the control section reads the delivery pressure signals P_a and P_b of the hydraulic pumps 2a and 2b detected by the pump delivery operating pressure detectors 13a and 13b, the

pressure signal S_{ia} detected by the operating pressure detector 12a, the pressure signal S_{ib} detected by the operating pressure detector 12d, the pressure signal S_{bm} detected by the boom elevation operating pressure detector 12b, the pressure signal S_{sw} detected by the swing operating pressure detector 12c, and the boom cylinder bottom pressure signal P_{bm} detected by the boom cylinder pressure detector 14.

[0021] Next, moving to procedure 21, the control section calculates the maximum delivery flows $Q_{a2} = g(P_a)$ and $Q_{b2} = g(P_b)$ of the hydraulic pumps 2a and 2b corresponding to the delivery pressure signals P_a and P_b within a range not exceeding a predetermined pump input horsepower based on the equivalent horsepower graph for predetermined pump input horsepower shown in Fig. 3. The control section also calculates the delivery flows $Q_{a1} = f(S_{ia})$ and $Q_{b1} = f(S_{ib})$ according to positive control of the hydraulic pumps 2a and 2b matching the pressure signals S_{ia} and S_{ib} based on the table shown in Fig. 4. As shown in Fig. 4, this table is set to a minimum flow Q_{min} up to a predetermined degree of operation S_{i1}, increased lineally between degrees of operation S_{i1} and S_{i2} from Q_{min} to a maximum flow Q_{max} allowed by control, then held at Q_{max} at greater than the degree of operation S_{i2}. Next, the control section calculates the maximum delivery flow $Q_{bm} = e(P_{bm})$ of the hydraulic pump 2b matching the boom cylinder bottom pressure signal P_{bm} within a range not exceeding a predetermined pump input horsepower based on the equivalent

horsepower graph for predetermined pump input horsepower shown in Fig. 3. As shown in Fig. 3, this Q_{bm} diminishes as P_{bm} increases.

[0022] Next, moving to procedure 22, the control section selects the lower of Q_{b1} and Q_{b2} calculated in procedure 21, and sets this as the target delivery flow Q_{b0} of the hydraulic pump 2b. Specifically, $Q_{b0} = Q_{b1}$ if $Q_{b1} < Q_{b2}$; otherwise, $Q_{b0} = Q_{b2}$.

[0023] Next, moving to procedure 25, the control section selects the lower of Q_{a1} and Q_{a2} calculated in procedure 21, and sets this as the target delivery flow Q_a of the hydraulic pump 2a. Specifically, $Q_a = Q_{a1}$ if $Q_{a1} < Q_{a2}$; otherwise, $Q_a = Q_{a2}$.

[0024] Following this, moving to procedure 28, the control section assesses whether the slewing boom is being raised — that is, whether $S_{sw} > S_{op}$ (= a blind area level used as a reference for assessing whether a pilot valve is being operated) — and whether $S_{bm} > S_{op}$. If the conditions of procedure 28 are satisfied, the control section assesses that the slewing boom is being raised and moves to procedure 29. In procedure 29, the control section selects the lower of $k \times Q_{bm}$, which is Q_{bm} calculated in procedure 21 multiplied by a coefficient k for determining if the swinging speed matches the boom elevation speed, and the target delivery flow Q_{b0} calculated in procedure 22, and sets this as the final target delivery flow Q_b of the hydraulic pump 2b. Specifically, $Q_b = Q_{b0}$ if $Q_{b0} < k \times Q_{bm}$, and $Q_b = Q_{b0}$ if $Q_{b0} \geq k \times Q_{bm}$. The process then moves to procedure 31. As shown

in Fig. 4, $k \times Q_{bm} \leq Q_{max}$ (maximum flow allowed by control). If the conditions of procedure 28 are not satisfied, the control section assesses that the slewing boom is not being raised, and in procedure 30, takes Q_{b0} found by procedure 22 as is as the final target delivery flow Q_b of the hydraulic pump 2b, then moves to procedure 31.

[0025] In procedure 31, the control section outputs a drive signal to the pump regulator 3a for making the delivery flow of the hydraulic pump 2a the target delivery flow Q_a, and outputs a drive signal to the pump regulator 3b for making the delivery flow of the hydraulic pump 2b the target delivery flow Q_b.

[0026] After procedure 31 has ended, the process returns to procedure 20 to repeat this calculation process.

[0027] During this control, first, the hydraulic pump 2a is always controlled based on a positive-control target delivery flow Q_{a1} matching the maximum operating pressure S_{ia} for the boom pilot valve 10. Specifically, the control section 15, in procedure 25, selects the lower of the positive-control target delivery flow Q_{a1} and the target delivery flow Q_{a2} according to horsepower control found by procedure 21 of Fig. 2, and outputs this selection to the regulator 3a in procedure 31.

[0028] Next, for the hydraulic pump 2b, the control section 15, in procedure 22, selects the lower of the positive-control target delivery flow Q_{b1} and the target delivery flow Q_{b2} according to horsepower control found by procedure 21 of Fig. 2, and sets this

selection as Q_{b0}. Next, the control section carries out a correction using $k \times Q_{bm}$ based on the boom load in procedure 29. Specifically, if the weight inside the bucket is light, producing a lighter load, Q_{bm} is greater as noted earlier, and hence, $k \times Q_{bm}$ is greater than Q_{b0}. Therefore, in procedure 29, the control section selects Q_{b0} to set $Q_b = Q_{b0}$. As a result, the regulator 3b exercises standard pump control using the positive-control target delivery flow Q_{b1} and the target delivery flow Q_{b2} according to horsepower control.

[0029] If the weight inside the bucket is heavy, producing a heavier load, $k \times Q_{bm}$ is less than Q_{b0}. Therefore, in procedure 29, the control section selects $k \times Q_{bm}$ to set $Q_b = k \times Q_{bm}$. As a result, the regulator 3b exercises pump control using $k \times Q_{bm}$, which is less than the standard target delivery flow Q_{b0}, and the target delivery flow Q_{b2} according to horsepower control. The delivery flow Q_b of the hydraulic pump 2b varies from a→b→d on the equivalent horsepower graph for predetermined input horsepower shown in Fig. 5. That is, when the boom load is heavier in this way, the hydraulic pump 21 is subjected to standard control using positive control and horsepower control as discussed earlier. As a result, the hydraulic pump 2a delivers the positive-control target delivery flow Q_{a1} or the target delivery flow Q_{a2} according to horsepower control. Because the load of the boom cylinder 8a is heavy at this time, however, the boom does not rise very far. Therefore, as discussed earlier, the delivery flow of the

hydraulic pump 2b is reduced to the extent that the boom does not rise, slowing the speed of the slewing motor 8b, which keeps a good balance between the degree of raising l_b and the degree of swinging θ_{sw} of the boom regardless of the load, allowing the relation between the degree of raising l_b and the degree of swinging θ_{sw} of the boom to vary from a→b→d as shown in Fig. 6.

[0030] By contrast, prior art, in which the delivery flow of the hydraulic pump 2b is not corrected as discussed earlier, always applies standard control to the hydraulic pump 2b based on the positive-control target delivery flow Q_{b1} and the target delivery flow Q_{b2} according to horsepower control. Consequently, the delivery flow of the hydraulic pump 2b varies as shown in Fig. 5 from a→b→c until reaching the maximum delivery flow Q_{max}. Therefore, the greater the degree of swinging in an operation, the more the degree of swinging must be adjusted according to the boom cylinder load. This embodiment can lessen the operational burden on the operator by not requiring a painstaking adjustment to match the movement path of the bucket.

[0031] Next, a second embodiment of the present invention will be discussed using Figs. 7 to 9. This embodiment is an embodiment for controlling the delivery flow of a pump using so-called negative control. Parts equivalent to parts of the first embodiment are labeled by the same reference numerals. Fig. 7 shows a hydraulic pressure circuit diagram of a hydraulic drive device according to this embodiment. The main points in Fig. 7 on which the hydraulic

drive device according to this embodiment differs from the hydraulic drive device of this first embodiment are that diaphragms 21a and 21b are disposed below the center bypass line of the direction switching valves 7a and 7f, differential pressure detectors 20a and 20b are disposed for detecting the pressure difference before and after these diaphragms 21a and 21b and outputting corresponding differential pressure signals P_{na} and P_{nb} to the control section 15, the operating pressure detectors 12a and 12d in the first embodiment are omitted, and the calculation process in the control section 15 differs due to this omission (to be discussed later). Otherwise, the configuration is about the same as the first embodiment.

[0032] The operation of the configuration discussed above will be discussed following Fig. 8, which shows a flowchart giving the details of the calculation process by the control section 15. In Fig. 8, first, in procedure 220, the control section reads the delivery pressure signals P_a and P_b of the hydraulic pumps 2a and 2b detected by the pump delivery operating pressure detectors 13a and 13b, the differential pressure signal P_{na} detected by the differential pressure detector 20a, the differential pressure signal P_{nb} detected by the differential pressure detector 20b, the pressure signal S_{bm} detected by the boom elevation operating pressure detector 12b, the pressure signal S_{sw} detected by the swing operating pressure detector 12c, and the boom cylinder bottom pressure signal P_{bm} detected by the boom cylinder pressure detector 14.

[0033] Next, moving to procedure 221, the control section calculates the maximum delivery flows $Q_{a2} = g(P_a)$ and $Q_{b2} = g(P_b)$ of the hydraulic pumps 2a and 2b corresponding to the delivery pressure signals P_a and P_b within a range not exceeding a predetermined pump input horsepower based on the equivalent horsepower graph for predetermined pump input horsepower shown in the same Fig. 3 as in the first embodiment. The control section also calculates the delivery flows $Q_{a1} = h(P_{na})$ and $Q_{b1} = h(P_{nb})$ according to negative control of the hydraulic pumps 2a and 2b matching the differential pressure signals P_{na} and P_{nb} based on the table shown in Fig. 9. As shown in Fig. 9, this table is set to a maximum flow Q_{max} allowed by control up to a predetermined negative-control differential pressure P_{n1}, decreased lineally between negative-control differential pressures P_{n1} and P_{n2} from Q_{max} to a minimum flow Q_{min}, then held at Q_{min} at greater than the negative-control differential pressure P_{n2}. Next, as in the first embodiment, the control section calculates the maximum delivery flow $Q_{bm} = e(P_{bm})$ of the hydraulic pump 2b matching the boom cylinder bottom pressure signal P_{bm} within a range not exceeding a predetermined pump input horsepower based on the equivalent horsepower graph for predetermined pump input horsepower shown in Fig. 3.

[0034] The following procedures 22 to 31 are about the same as in the first embodiment, and will not be discussed again. After procedure 31 has ended, the process returns to procedure 220 to

repeat this calculation process.

[0035] During this control, first, the hydraulic pump 2a is always controlled based on a negative-control target delivery flow Q_{a1} matching the negative-control differential pressure P_{na}. Specifically, the control section 15, in procedure 25, selects the lower of the negative-control target delivery flow Q_{a1} and the target delivery flow Q_{a2} according to horsepower control found by procedure 221 of Fig. 8, and outputs this selection to the regulator 2a [sic] in procedure 31.

[0036] Next, for the hydraulic pump 2b, the control section 15, in procedure 22, selects the lower of the positive-control target delivery flow Q_{b1} and the target delivery flow Q_{b2} according to horsepower control found by procedure 221 of Fig. 8, and sets this selection as Q_{b0}. Next, if the internal weight is light and the boom load is lighter, $k \times Q_{bm}$ is greater than Q_{b0}. Hence, the control section selects Q_{b0} in procedure 29, and the regulator 3b exercises standard pump control using the positive-control target delivery flow Q_{b1} and the target delivery flow Q_{b2} according to horsepower control.

[0037] If the weight inside the bucket is heavy, producing a heavier load, $k \times Q_{bm}$ is less than Q_{b0}, in procedure 29. Hence, the control section selects $k \times Q_{bm}$ to set $Q_b = k \times Q_{bm}$. As a result, the regulator 3b exercises pump control using $k \times Q_{bm}$, which is less than the standard target delivery flow Q_{b0}, and the target delivery flow Q_{b2} according to horsepower control. That is, as in the first embodiment,

the delivery flow of the hydraulic pump 2b is reduced to the extent that the boom does not rise, slowing the speed of the slewing motor 8b, which keeps a good balance between the degree of raising l_b and the degree of swinging θ_{sw} of the boom regardless of the load.

[0038] This embodiment obtains the same effects as the first embodiment.

[0039] [EFFECTS OF THE INVENTION]

The present invention reduces the delivery flow from the first variable-displacement pump and slows the swinging speed to a corresponding extent even if the boom elevation speed is slow, thus keeping a good balance between the degree of raising and the degree of swinging of the boom. Therefore, the present invention can lessen the operational burden on the operator by not requiring a painstaking adjustment to match the movement path of the bucket.

[BRIEF EXPLANATION OF THE DRAWINGS]

FIG. 1 is a hydraulic pressure circuit diagram of a hydraulic drive device according to a first embodiment of the present invention.

FIG. 2 is a diagram showing a flowchart giving the details of the calculation process by the control section shown in Fig. 1.

FIG. 3 is an equivalent horsepower graph for predetermined pump input horsepower used in the calculation process of the flowchart shown in Fig. 2.

FIG. 4 is a diagram showing the relation between degree of

operation and pump delivery flow used in the calculation process of the flowchart shown in Fig. 2.

FIG. 5 is a diagram showing change in the delivery flow of a hydraulic pump.

FIG. 6 is a diagram showing the relation between degree of raising and degree of swinging a boom.

FIG. 7 is a hydraulic pressure circuit diagram of a hydraulic drive device according to a second embodiment of the present invention.

FIG. 8 is a diagram showing a flowchart giving the details of the calculation process by the control section shown in Fig. 7.

FIG. 9 is a diagram showing the relation between a differential pressure signal and pump delivery flow used in the calculation process of the flowchart shown in Fig. 8.

[EXPLANATION OF THE REFERENCE NUMERALS]

1 Engine

2a Hydraulic pump (second variable-displacement hydraulic pump)

2b Hydraulic pump (first variable-displacement hydraulic pump)

3a, b Regulator (pump control means)

4 Pilot pump

5b to e Shuttle valve

6a, b Pipe line

7a Boom direction switching valve

7b Swinging direction switching valve

7c Right travel direction switching valve

7d Bucket direction switching valve

7e Arm direction switching valve

7f Left travel direction switching valve

8a Boom cylinder

8b Slewing motor

10 Boom pilot valve (second operating means)

10A Operating lever

11 Swinging pilot valve (first operating means)

12a Operating pressure detector (second degree of operation detecting means)

12b Boom elevation operating pressure detector

12c Swing operating pressure detector

12d Operating pressure detector (first degree of operation detecting means)

13a, b Pump delivery pressure detector

14 Boom cylinder pressure detector (load detecting means)

15 Control section (setting means and limiting means)

16a, b Pipe

17a, b Signal port

18a, b Pipe

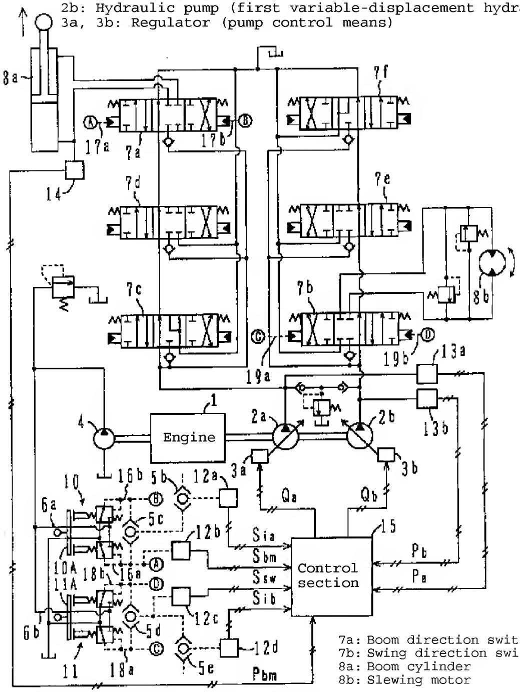
19a, b Signal port

20a, b Differential pressure detector (pressure detecting means)

21a, b Diaphragm (resistance means)

FIG. 1

2a: Hydraulic pump (second variable-displacement hydraulic pump)
2b: Hydraulic pump (first variable-displacement hydraulic pump)
3a, 3b: Regulator (pump control means)



7a: Boom direction switching valve
7b: Swing direction switching valve
8a: Boom cylinder
8b: Slewing motor

10: Boom pilot valve (second operating means)
11: Swing pilot valve (first operating means)
12a: Operating pressure detector (second degree of operation detecting means)
12b: Boom operating pressure detector
12c: Swing operating pressure detector
12d: Operating pressure detector (first degree of operation detecting means)

14: Boom cylinder pressure detector (load detecting means)
15: Control section (setting means, control means)

FIG. 2

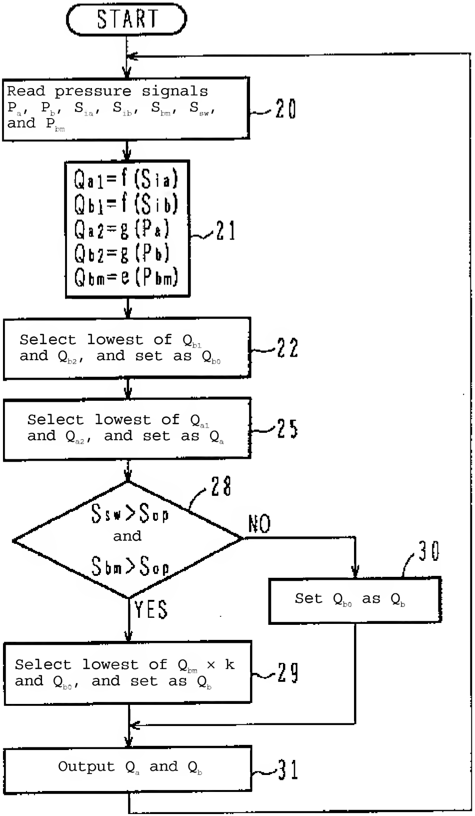
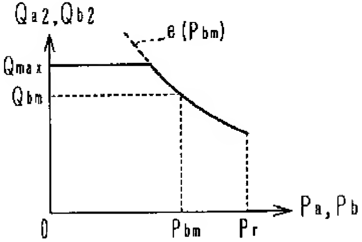
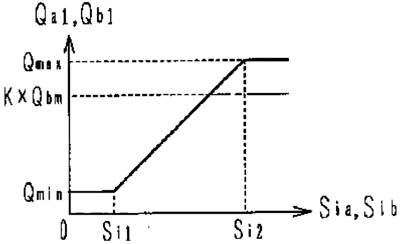

START
Read pressure signals P_a, P_b, S_{ia}, S_{ib}, S_{bm}, S_{sw}, and P_{bm}
20
$Q_{a1}=f(S_{ia})$
$Q_{b1}=f(S_{ib})$
$Q_{a2}=g(P_a)$
$Q_{b2}=g(P_b)$
$Q_{bm}=e(P_{bm})$
21
Select lowest of Q_{b1} and Q_{b2}, and set as Q_{b0}
22
Select lowest of Q_{a1} and Q_{a2}, and set as Q_a
25
$S_{sw}>S_{op}$ and $S_{bm}>S_{op}$
28
NO
YES
Set Q_{b0} as Q_b
30
Select lowest of $Q_{bm}\times k$ and Q_{b0}, and set as Q_b
29
Output Q_a and Q_b
31

FIG. 3



Qa2,Qb2
e (Pbm)
Qmax
Qbm
0
Pbm
Pr
Pa, Pb

FIG. 4



Qa1,Qb1
Qmax
K×Qbm
Qmin
0
Si1
Si2
Sia,Sib

FIG. 5

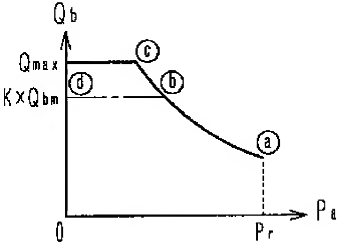


FIG. 6

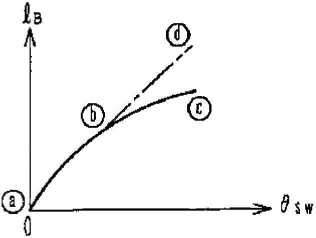
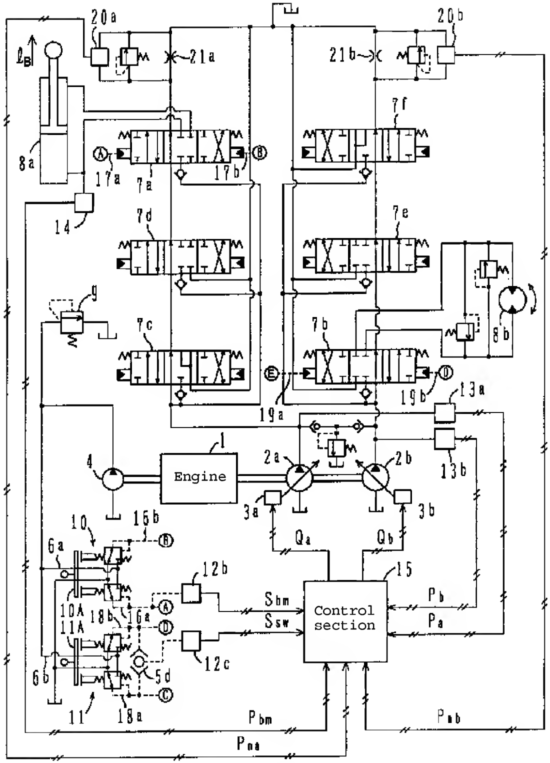


FIG. 7



20a, 20b: Differential pressure detector (pressure detecting means)
21a, 21b: Diaphragm (resistance means)

FIG. 8

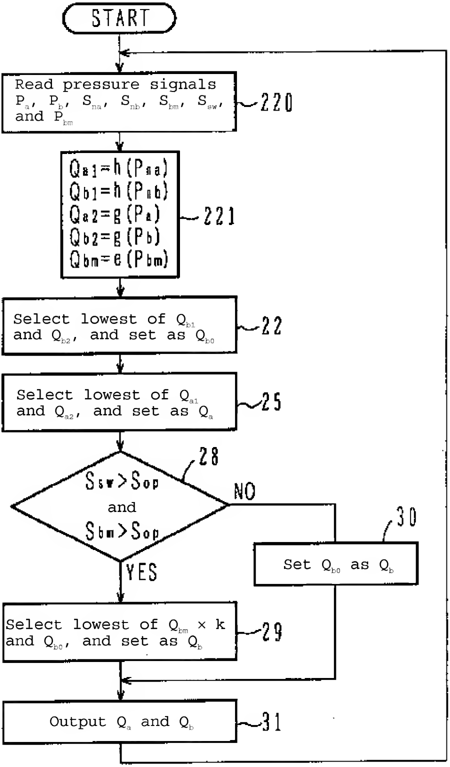

START
Read pressure signals
Pa, Pb, Sna, Snb, Sbm, Ssw,
and Pbm
220
Qa1=h(Pna)
Qb1=h(Pnb)
Qa2=g(Pa)
Qb2=g(Pb)
Qbm=e(Pbm)
221
Select lowest of Qb1
and Qb2, and set as Qb0
22
Select lowest of Qa1
and Qa2, and set as Qa
25
28
Ssw>Sop
and
Sbm>Sop
NO
YES
30
Set Qb0 as Qb
Select lowest of Qbm × k
and Qb0, and set as Qb
29
Output Qa and Qb
31

FIG. 9